Queen Charlotte Islands TSA
Timber Supply Analysis Adjustment
FIP File Adjustment Process

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Executive Summary

This report outlines a proposed adjustment process for the Queen Charlotte Islands (QCI) TSA FIP file, as discussed at the October 9, 1998 meeting of the project team. It has been updated to February 12, 1999 and reflects the final recommendations of the project team. The project team consisted of staff from the Ministry of Forests (MOF) Resources Inventory Branch, Timber Supply Branch, Vancouver Forest Region, and the Queen Charlotte Islands Forest District and consultants. The project team members are identified on the project endorsement sheet in the next section of this report.

The adjustment process has the following features:

- Its purpose is to adjust the existing FIP file to account for the bias detected by the inventory audit and the volume and decay monitoring studies.
- The population of interest for adjustment is the mature polygons in the operable land base in the QCI TSA.
- It uses the inventory audit and the volume and decay monitoring data.
- No new sampling is needed to account for the possible change in the operable land base since the 1997 sampling.
- The ratio model is used to adjust age, top height and volume.
- The volume ratios are based on volume net decay only, and volume net decay, waste and breakage. For timber supply analysis the MOF recommends a utilization level net decay, waste and breakage.
- Two types of volume ratios were provided: volume ratios with veteran trees and volume ratios without veteran trees. For timber supply analysis, the MOF recommends that ratios that include veteran trees be applied.
- The ratios are developed by strata defined as: Cedar leading less than 200 years of age; Cedar leading greater than or equal to 200 years of age; Hemlock leading, SI<15; Hemlock leading, SI>=15; and Spruce leading.
- The overall inventory adjustment without the taper and loss factors adjustments was negligible. The adjustment with the taper and loss factors adjustments was 1.140 (Table 9), and that without was 0.995 (Table 13).

Some of the important assumptions were:

1. The inventory audit sample is unbiased. In particular, the possible change in total area of the operable land base does not affect the

representativeness of the audit sample.
2. The relationship of the inventory values to the audit values can be described by a ratio, i.e., and a straight line through the origin.
3. The strata sample sizes used to calculate the ratios are adequate.

We recommend that the proposed adjustment method be implemented, after an impact analysis to determine the magnitude of the changes to attributes and volume when the ratios proposed in this report are applied to the FIP file.

PROJECT ENDORSEMENT SHEET

The following list identifies and acknowledges the project team members involved in the development of recommendations for the statistical adjustment of the Queen Charlotte Islands TSA FIP File. It is understood that the specific application of the results in this report will be the responsibility of the MOF Timber Supply Branch in consultation with the regional timber supply analyst.

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1. INTRODUCTION

1.1 BACKGROUND

The state of the current inventory in the Queen Charlotte TSA has been in question. In 1992, several cruise plots were established in the QCI as part of a volume and decay monitoring project. At the same time, a new inventory (polygon delineation and attribute estimation) was being concluded in the TSA portion of the QCI. Out of the decay sampling plots, 17 plots fell in the mature (120 years+) forested portion of the TSA. These data were used to check the old and new inventory volumes in the TSA.

Analyses based on these 17 samples showed significant over-estimation of the old timber volume (approximately 28%). The audit volume was 522 m^3/ha $\pm$ 13.4% and the existing inventory volume 669 m^3/ha. However, the audit volume was not significantly different from the new inventory volumes for the entire TSA. The audit volume based on re-delineated sample polygons was 546 m^3/ha and the corresponding new inventory volume was 608 m^3/ha. Similar conclusions were obtained from the 13 samples (out of the total 17) that fell in the operable land base. The audit average volume based on re-delineated sample polygons in the operable land base was 557 m^3/ha $\pm$ 13.7% and the corresponding new inventory average volume was 638 m^3/ha.

A new Timber Supply Review (TSR) for the TSA, incorporating the new inventory information, was initiated. An inventory audit project was initiated in 1997 to ascertain the accuracy of the inventory in the QCI, as part of this new analysis. The objectives of this project were:

1. To confirm the results of the earlier inventory audit of the overall mature timber volumes in the operable land base of the TSA.
2. To estimate strata-based ratios for adjusting the QCI TSA FIP file height, age and volume.
3. To incorporate the ratio adjustments from the volume and decay monitoring project into the stand volume estimation process. The ratio adjustments correct the FIZ-based species-specific estimates of Close "U" merchantable volume, net decay, waste and breakage.

The new inventory audit samples established in the operable landbase of the TSA during the 1997 field season, along with the results of the volume and decay monitoring project, are the bases of the proposed FIP file adjustment for the QCI.

1.2 Document Objectives

This report outlines the proposed adjustment process for the QCI TSA discussed at the October 9, 1998 meeting of the project team. The project team included the Ministry of Forests Resources Inventory Branch, Timber Supply Branch, Region, and District staff. The intent is that this project team will review and endorse the recommendations in this report (Section 3).

2. THE ADJUSTMENT PROCESS

2.1 Overview

The adjustment process is a set of steps and assumptions used to develop and apply factors to adjust the TSA FIP file attributes (top height and age) and the volume predicted using VDYP. The adjustment is expected to remove the overall bias detected by the inventory audit and the tree volume and decay monitoring studies. Details of the adjustment process are outlined below.

2.2 Data Source

Inventory Audit

The inventory audit data was obtained from 67 sample clusters installed in the QCI TSA. The sample clusters were selected with equal probability from a sorted list of polygons over the entire mature stand component (60 years+) of the operable land base in the TSA. The data for each sample cluster included average volume/ha, top height, age, and species composition (by basal area). The volumes per hectare were re-compiled using FIZ-based species-specific taper and loss factor adjustments (Appendix I).

The 1992 inventory audit data were not used mainly because of the following reasons:

- It would be almost impossible to properly weight the 1992 observations to account for growth between 1992-1997, without taking further growth measurements.
- Weighting of the 1992 and 1997 observations (if we ignore growth of the 1992 sample) would be possible; however, the 1992 sample would not improve the sampling errors of the overall or strata estimates by any significant amount. For example, increasing the sample size from 67 observations to, say, 80, would reduce the sampling error (95% probability) of the overall audit volume by only about 0.9% (from 9.8% to 8.9%) (the CV of volume was approximately 40%).
- Re-stratifying and re-compiling the data for the partitioned

polygons is time consuming, yet the re-stratification and recompilation are at best a rough approximation and the sampling error benefits are negligible. (Proper re-compilation would require a re-cruise of the partitioned original samples to check for "in" trees.)

Volume and Decay Monitoring[1]

The objectives of the volume and decay monitoring project were:

1. To implement and assess a newly developed unbiased volume and decay sampling methodology.
2. To obtain a random sample of trees that will be destructively sampled to obtain actual volume, decay and waste.
3. To use the actual and estimated volumes to develop unbiased adjustments applicable to standard estimates of volume decay and waste.

The population of interest was the entire forested land base within the TSA and TFLs on the Queen Charlotte Islands. A two-step process was used to obtain the sample tree data.

Step One

- Random Selection of polygons using randomly generated latitude and longitude coordinates.
- Selected polygons were stratified into mature (over 140 years) and immature (40 to 140 years) age classes as defined by polygon label.
- Mature polygons were further stratified by 'Yield Analysis Contribution Class' (YAC), composed of 4 classes:
    - YAC 1- operable, part of 20 year cutting profile.
    - YAC 2 - operable, part of 20 to 50 cutting profile.
    - YAC 3 - inoperable and productive.
    - YAC 4 - inoperable and non-productive.
- A subsample of each YAC group of mature polygons was randomly selected; the majority of the sample polygons were in the YAC 1 class.
- All immature polygons were selected.
- A grid of cruise prism plots, ranging from 4 to 8 full measure with 8 to 16 count plots depending on polygon area, were established in each selected polygon sample polygon. All trees were cruised using MOF Revenue Branch standards and procedures.

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[1] Will Smith, Ministry of Forests Resources Inventory Branch, Victoria, BC, provided the notes in this section.

The total number of mature and immature sample polygons are shown in Table 1.

Table 1. Number of Sample Polygons by Age Group, Tenure and Yield Analysis Contribution Class (YAC)

AGE GROUP	TENURE	YAC 1	YAC 2	YAC 3	YAC 4	Total
Immature	TSA	1	5	1	2	9
Immature	TFL	10	0	0	0	10
Mature	TSA	12	3	2	1	18
Mature	TFL	23	1	0	1	25
Total	All tenures	46	9	3	4	62

Step Two

Decay and Waste Sampling:

- The trees tallied in the cruise plots were pooled and stratified into groups based on tree species, risk groups, two age classes, four dbh classes and two slope classes.
- A random sample of trees was selected from each grouping, with the majority of trees selected from the under 50% slope class.

Destructive Sampling:

- Destructive sampling used the Resources Inventory Branch volume and decay sampling standards and procedures.
- Decay sample trees were felled and bucked into standard 2.5 m or 5.0 meters lengths, depending on dbh. Decay and gross volume measures were collected for each section.

The total numbers of decay sample trees are shown in Table 2.

Table 2. Number of decay and waste sample trees.

Species	Risk Group	Immature Age Group	Mature Age Group	Total Trees
Cw	1	47	50	97
	2	18	85	103
H spp	1	76	71	147
	2	15	56	71
	3	2	30	32
Ss	1	77	59	136
	2	3	40	43
Y	1	0	46	46
	2	0	73	73
Totals		238	510	748

Actual and estimated tree gross, merchantable and net merchantable (less decay and waste) volumes were calculated using Resources Inventory Branch tree compiler. Estimated volumes were based on:

- FIZ-based Taper Equation: Kozak's (1988) variable exponent taper equation (version 4.1).
- FIZ-based Loss Factors for Decay and Waste2: the 1976 MOF metric diameter-class, decay, waste and breakage factors.

The data were analysed by Dr. Jim Flewelling who developed unbiased ratio adjustments to correct FIZ-based specis-specific estimates of close "u" merchantable volume, net decay and waste. The results of the analysis indicate that the current taper equations and loss factors under-estimate net volume in all the species. Western Redcedar was under-estimated by 67%, Hemlock by 6%, Spruce by 7% and Yellow Cedar by 29%.

These results were incorporated into the inventory audit analysis by recompiling the audit data using the FIZ-based ratio adjustments that better accounted for taper, decay and waste in the QCI. These adjustment factors and the recompilation algorithms are given in Appendix I.

2.2 Population for adjustment

The population of interest for adjustment is all the mature polygons (60 years +) in the operable land base in the Queen Charlotte Islands TSA during the TSR in 1998/9. The population that was sampled in the inventory audit was the mature timber in the operable land base in the Queen Charlotte Islands TSA in the 1997 field season. Since that time, there may have been some changes to the operable land base of the TSA. However, the distribution of the 1997 population is expected to be similar to that of the new 1998/9 population. Once the TSA file has been completely finalized, the changes in site, age, species composition, etc. should be evaluated to confirm that they are minor.

2.3 Stratification

The inventory audit sample was selected from the entire population and post-stratified into four strata defined by the project team (Table 3).[2] It is not clear if there are any polygons in the population that do not belong to one of these strata. If there are, then those polygons should not be adjusted.

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[2] The hemlock strata are defined based on site, and the cedar strata are defined based on age. As a result, strata assignments may change after the age and height attributes are adjusted.

Table 3. Initial strata definitions, areas, sample sizes, and sampling errors.

Stratum	Timber harvesting land-base (%)	Number of audit sample clusters	Sampling error[3] for mean inventory volume/ha (%)	Sampling error for mean audit volume/ha (%)
Cedar leading, <200 years old	16.4	11	18.2	27.3
Cedar leading, >=200 years old	27.0	18	12.0	22.4
Hemlock, SI<15	26.4	12	8.2	17.1
Hemlock, SI>=15	16.2	14	5.6	18.2
Spruce leading	14.0	12	5.1	26.3
Total	100.0	67	7.5	9.8

2.4 Sample Size

The overall total sample size of 67 observations was considered (based on sampling error) sufficient for evaluating the inventory volumes versus audit volumes. The sampling error of the overall audit volume was 9.8% (Table 3). The strata sample sizes, which ranged from 11-18, were also considered reasonable for purposes of adjusting strata attributes. The sampling error of the strata ratios for age and height ranged from 17-25% and 7-13%, respectively (Tables 4 and 5).

2.5 Adjustment Factors

The ratio-of-means estimator was chosen to derive the adjustment factors for the attributes and volume. We chose the ratio method to be consistent with the Fraser TSA approach, which is currently the official MOF adjustment methodology[4]. Least squares regression and the geometric mean regression (GMR) were also fit; their performance (measured by the distribution of the residuals) was generally similar to that of the ratio in most cases.

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[3] The sampling error corresponding to the ± 95% confidence interval expressed as a percentage of the mean volume/ha estimate. Inventory volume is net decay and audit volume is net decay, without veteran trees and no taper and loss factor adjustment.

[4] Dr. Sam Otukol, Forest Biometrician, Resources Inventory Branch, Victoria, BC.

2.5.1 Attributes

Adjustment factors for age and top height were derived for each stratum based on the ratio-of-means model that related the audit attributes to the inventory attributes. The ratio for age was calculated as

$$ratio = \frac{age_{audit}}{age_{inventory}}$$

where age_{audit} is the average age based on the audit samples in a stratum and $age_{inventory}$ is the average inventory age in the FIP file for the sampled polygons. The ratio for top height was calculated in a similar manner.

The strata ratios of age and height are given in Table 4 and Table 5, respectively.

Table 4. Ratios for inventory age adjustment.

Stratum	n[5]	Ratio[6]	± Sampling error (%) for ratio[7]	Correlation coefficient (p-values)
Cedar leading, <200 years old	11	1.0904	25.5	0.3031 (0.3649)
Cedar leading, >=200 years old	18	0.7801	17.5	-0.1595 (0.5274)
Hemlock, SI<15	11	0.8319	28.0	-0.3029 (0.3653)
Hemlock, SI>=15	14	0.9761	13.3	0.5106 (0.0621)
Spruce leading	11	0.8022	21.9	-0.0794 (0.8166)
Overall	65	0.8626	8.5	

[5] Note that 2 samples were excluded because ground attributes were missing (in hemlock and spruce strata).

[6] The overall ratio is unweighted.

Table 5. Ratios for inventory top height adjustment.

Stratum	n[8]	Ratio[9]	± Sampling error (%) for ratio[10]	Correlation coefficient (p-values)
Cedar leading, <200 years old	11	0.9819	13.2	0.3003 (0.3696)
Cedar leading, >=200 years old	18	0.8988	8.3	0.5906 (0.0099)
Hemlock, SI<15	11	1.0274	8.9	0.7164 (0.0131)
Hemlock, SI>=15	14	0.9826	7.5	0.0138 (0.9625)
Spruce leading	11	0.8577	12.1	0.6000 (0.0510)
Overall	65	0.9444	4.2	

These ratios indicate varying magnitudes of biases in inventory age and height. These biases could be the result of errors in the photo estimates and inventory update or differences in the implementation of attribute definitions between photo-estimation and audit sampling. It is not possible in this study to partition the observed attribute biases into these two sources of error.

Correlation coefficients that measure the strength of the linear relationship between the audit and inventory heights or ages are also included in Table 4 and Table 5. Note that ratio adjustments are always made (when a bias is detected) regardless of the size of the correlation coefficient. The size of the correlation is not used to decide whether an adjustment should be made or not; it measures the quality of the adjustment. The scatter plots and residual analysis of the adjusted attributes are provided in section 2.6.

2.5.2 Strata re-assignment

The variables used to define four of the strata -- age and site index - were affected by the attribute adjustment. Therefore, the strata assignments were reassessed after the age and height adjustments were applied to the samples. There were no changes to the Cedar strata. However, for the Hemlock strata, 4 samples were re-assigned from the "Hemlock, SI<15" strata to the "Hemlock, SI>=15" strata and 4 samples

[7] Based on a 95% confidence interval.

[8] Note that 2 samples were excluded because ground attributes were missing (in hemlock and spruce strata).

[9] The overall ratio is unweighted.

were re-assigned from the "Hemlock, SI>=15" strata to the "Hemlock, SI<15" strata. These new strata assignments became the basis for the volume adjustment described below.

2.5.3 Volume

The adjustment factor for volume was derived for each stratum in a two-step process:

1. For each sample polygon, the inventory age and height were adjusted using the ratios in Table 4 and Table 5, respectively. These adjusted age and height were used as input for VDYP to predict a 'revised' inventory volume.
2. A ratio was then calculated between this 'revised' inventory volume and the observed audit volume in a manner similar to the attributes.

Volume adjustment ratios, that incorporated the taper and loss factors adjustments in the audit volumes, were calculated by strata:

- Using volume with veteran trees net decay only and net decay waste and breakage (Tables 6 and 7)
- Using volume without veteran trees net decay only and net decay waste and breakage (Tables 8 and 9).

Volume ratios based on the audit volume *not* adjusted by the taper and loss factors adjustments were also calculated:

- Using volume with veteran trees net decay and net decay, waste and breakage (Tables 10 and 11).
- Using volume without veteran trees net decay and net decay waste and breakage (Tables 12 and 12).

The project team must decide which of these sets of ratios to apply. The residual analyses are given in Section 2.6

[10] Based on a 95% confidence interval.

Table 6. Ratios for inventory volume adjustment[11] with veteran trees included, with taper and loss factor adjustment, volume net decay only.

Stratum	n	Ratio[12]	± Sampling error (%) for ratio[13]	Correlation coefficient (p-values)
Cedar leading, <200 years old	11	1.5165	25.1	0.4003 (0.2225)
Cedar leading, >=200 years old	18	1.2635	21.7	0.2066 (0.4109)
Hemlock, SI<15	12	1.0262	15.5	0.3116 (0.3242)
Hemlock, SI>=15	14	1.0540	19.5	-0.2133 (0.4640)
Spruce leading	12	0.9687	21.8	0.4081 (0.1879)
Overall	67	1.1207	8.9	

Table 7. Ratios for inventory volume adjustment with veteran trees, with taper and loss factor adjustment, volume net decay, waste and breakage.

Stratum	n	Ratio[14]	± Sampling error (%) for ratio[15]	Correlation coefficient (p-values)
Cedar leading, <200 years old	11	1.6523	26.5	0.3530 (0.2869)
Cedar leading, >=200 years old	18	1.3536	21.8	0.2244 (0.3707)
Hemlock, SI<15	12	1.0537	15.4	0.3525 (0.2611)
Hemlock, SI>=15	14	1.0703	20.0	-0.2936 (0.3082)
Spruce leading	12	0.9744	22.3	0.4349 (0.1577)
Overall	67	1.1588	9.3	

[11] The inventory volume is predicted from the VDYP model using the adjusted ages and heights (i.e., inventory ages and heights adjusted based on ratios in Table 4 and Table 3 respectively.

[12] The overall ratio is unweighted.

[13] Based on a 95% confidence interval.

[14] The overall ratio is unweighted.

[15] Based on a 95% confidence interval.

Table 8. Ratios for inventory volume adjustment[16] without veteran trees, with taper and loss factor adjustment, volume net decay only.

Stratum	n	Ratio[17]	± Sampling error (%) for ratio[18]	Correlation coefficient (p-values)
Cedar leading, <200 years old	11	1.4385	25.4	0.3267 (0.3268)
Cedar leading, >=200 years old	18	1.2229	21.8	0.2445 (0.3282)
Hemlock, SI<15	12	1.0200	15.9	0.3051 (0.3349)
Hemlock, SI>=15	14	1.0540	19.5	-0.2133 (0.4640)
Spruce leading	12	0.9642	22.1	0.3965 (0.2020)
Overall	67	1.1020	8.8	

Table 9. Ratios for inventory volume adjustment without veteran trees, with taper and loss factor adjustment, volume net decay, waste and breakage.

Stratum	n	Ratio[19]	± Sampling error (%) for ratio[20]	Correlation coefficient (p-values)
Cedar leading, <200 years old	11	1.5726	26.7	0.2911 (0.3852)
Cedar leading, >=200 years old	18	1.3117	21.8	0.2600 (0.2974)
Hemlock, SI<15	12	1.0478	15.8	0.3466 (0.2698)
Hemlock, SI>=15	14	1.0703	20.0	-0.2936 (0.3082)
Spruce leading	12	0.9699	22.6	0.4241 (0.1694)
Overall	67	1.1403	9.2	

[16] The inventory volume is predicted from the VDYP model using the adjusted ages and heights (i.e., inventory ages and heights adjusted based on ratios in Table 4 and Table 3 respectively.

[17] The overall ratio is unweighted.

[18] Based on a 95% confidence interval.

[19] The overall ratio is unweighted.

[20] Based on a 95% confidence interval.

Table 10. Ratios for inventory volume adjustment with veteran trees, no taper and loss factor adjustment, volume net decay only.

Stratum	n	Ratio[21]	± Sampling error (%) for ratio[22]	Correlation coefficient (p-values)
Cedar leading, <200 years old	11	1.3868	28.3	0.3273 (0.3259)
Cedar leading, >=200 years old	18	1.0365	22.5	0.2282 (0.3625)
Hemlock, SI<15	12	0.9382	16.2	0.2757 (0.3858)
Hemlock, SI>=15	14	0.9523	20.1	-0.2700 (0.3506)
Spruce leading	12	0.8798	24.2	0.4356 (0.1570)
Overall	67	0.9969	9.3	

Table 11. Ratios for inventory volume adjustment with veteran trees, no taper and loss factor adjustment, volume net decay, waste and breakage.

Stratum	n	Ratio[23]	± Sampling error (%) for ratio[24]	Correlation coefficient (p-values)
Cedar leading, <200 years old	11	1.4912	30.8	0.2623 (0.4360)
Cedar leading, >=200 years old	18	1.0597	23.5	0.2524 (0.3123)
Hemlock, SI<15	12	0.9476	16.6	0.3192 (0.3119)
Hemlock, SI>=15	14	0.9414	20.7	-0.3435 (0.2292)
Spruce leading	12	0.8705	25.4	0.4755 (0.1182)
Overall	67	1.0061	9.9	

[21] The overall ratio is unweighted.
[22] Based on a 95% confidence interval.
[23] The overall ratio is unweighted.
[24] Based on a 95% confidence interval.

Table 12. Ratios for inventory volume adjustment without veteran trees, no taper and loss factor adjustment, volume net decay only.

Stratum	n	Ratio[25]	± Sampling error (%) for ratio[26]	Correlation coefficient (p-values)
Cedar leading, <200 years old	11	1.3322	28.3	0.2776 (0.4086)
Cedar leading, >=200 years old	18	1.0088	22.5	0.2623 (0.2930)
Hemlock, SI<15	12	0.9342	16.5	0.2722 (0.3920)
Hemlock, SI>=15	14	0.9523	20.1	-0.2700 (0.3506)
Spruce leading	12	0.8754	24.4	0.4250 (0.1684)
Overall	67	0.9837	9.2	

Table 13. Ratios for inventory volume adjustment without veteran trees, no taper and loss factor adjustment, volume net decay, waste and breakage.

Stratum	n	Ratio[27]	± Sampling error (%) for ratio[28]	Correlation coefficient (p-values)
Cedar leading, <200 years old	11	1.4430	30.7	0.2281 (0.4999)
Cedar leading, >=200 years old	18	1.0347	23.5	0.2831 (0.2550)
Hemlock, SI<15	12	0.9456	16.7	0.3175 (0.3145)
Hemlock, SI>=15	14	0.9415	20.7	-0.3434 (0.2293)
Spruce leading	12	0.8661	25.6	0.4662 (0.1266)
Overall	67	0.9950	9.8	

[25] The overall ratio is unweighted.
[26] Based on a 95% confidence interval.
[27] The overall ratio is unweighted.
[28] Based on a 95% confidence interval.

2.6 Residual (bias) Analysis

A residual analysis was conducted to check for biases when adjustment ratios were applied to the FIP file. Bias, measured by the difference (audit value - inventory value), was calculated for the sampled polygons and plotted against the adjusted value separately for each attribute and for volume. Results for the volume residual analysis are presented for only the inventory volume adjustment without veteran trees, with the new taper and loss factor adjustment, and volume net of decay, waste and breakage (using the volume adjustment ratios from Table 10).

2.6.1 Attributes

Scatter plots of the original observations and residuals of the adjusted attributes (height and age) are shown by strata in Figures 1 through 4. The residual graphs indicated no apparent trend for adjusted age or adjusted height bias with respect to age (Figure 3). There was a slight bias in adjusted height for young redcedar; the ratio model underestimated height for short stands and overestimated height for tall stands (Figure 4).

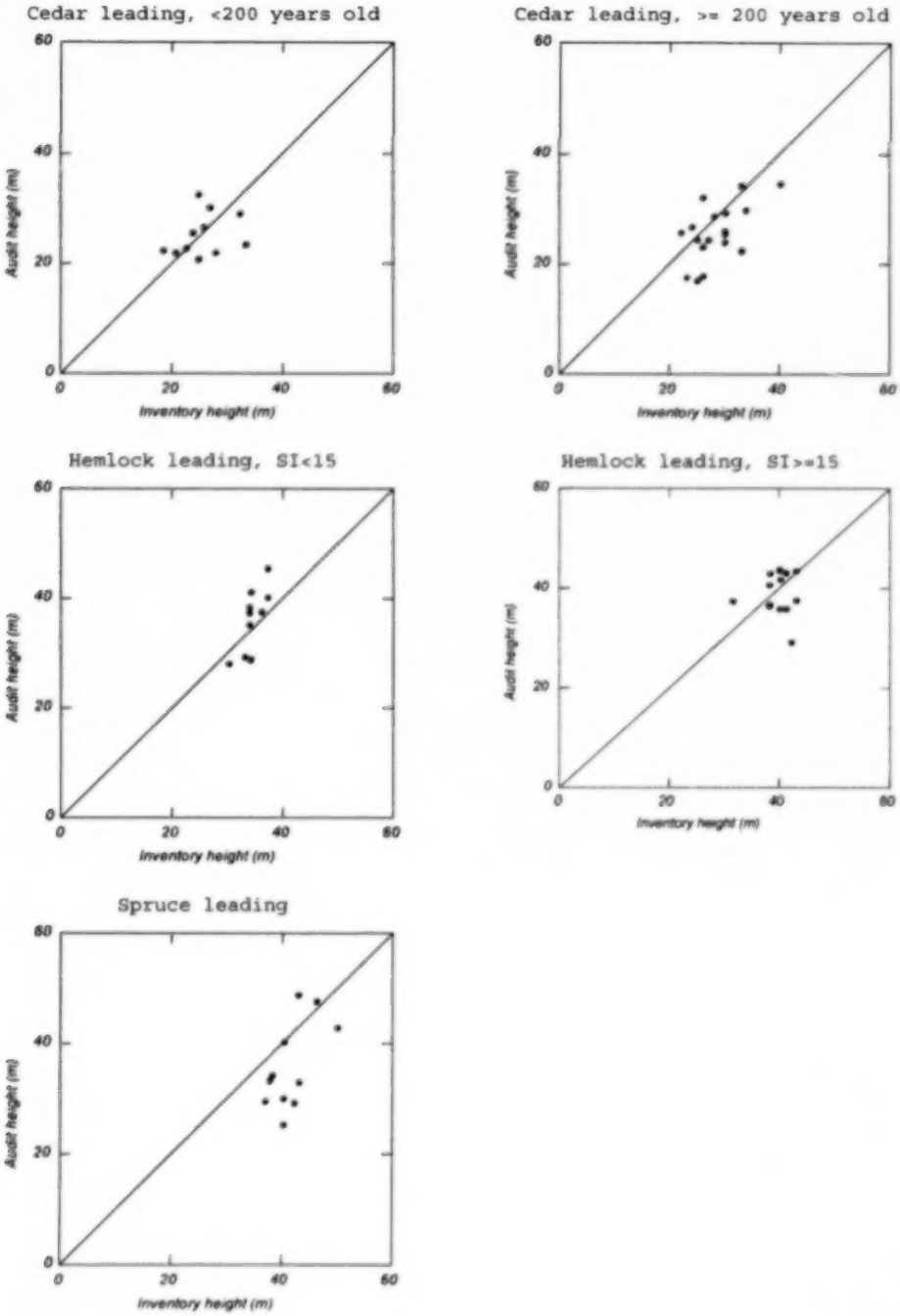
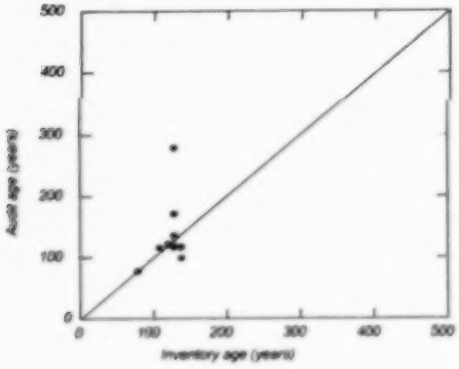
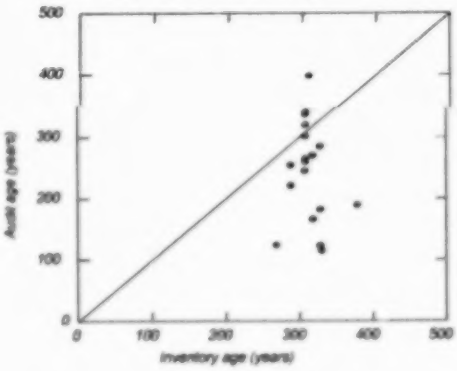


Figure 1. Scatter plots for height, by strata.

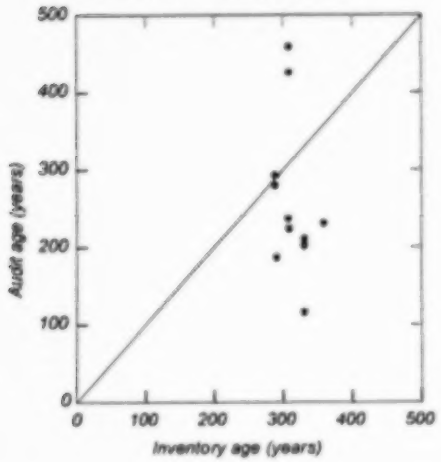
Cedar leading, <200 years old



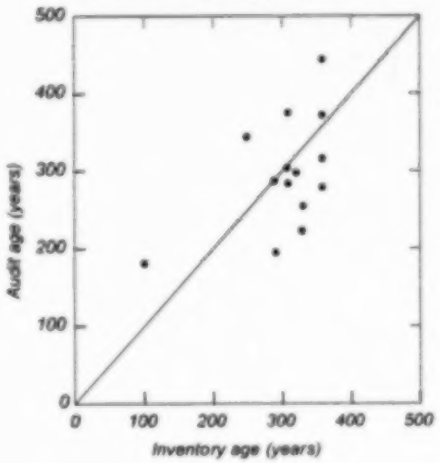
Cedar leading, >= 200 years old



Hemlock leading, SI<15



Hemlock leading, SI>=15



Spruce leading

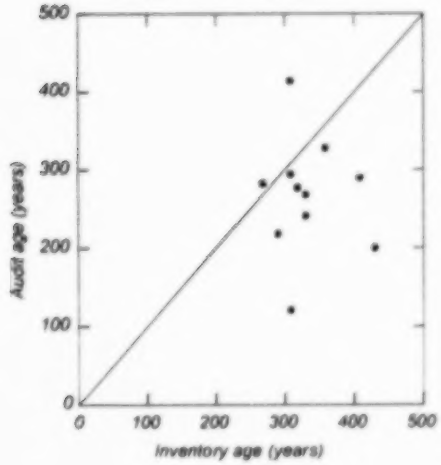


Figure 2. Scatter plots for age, by strata.

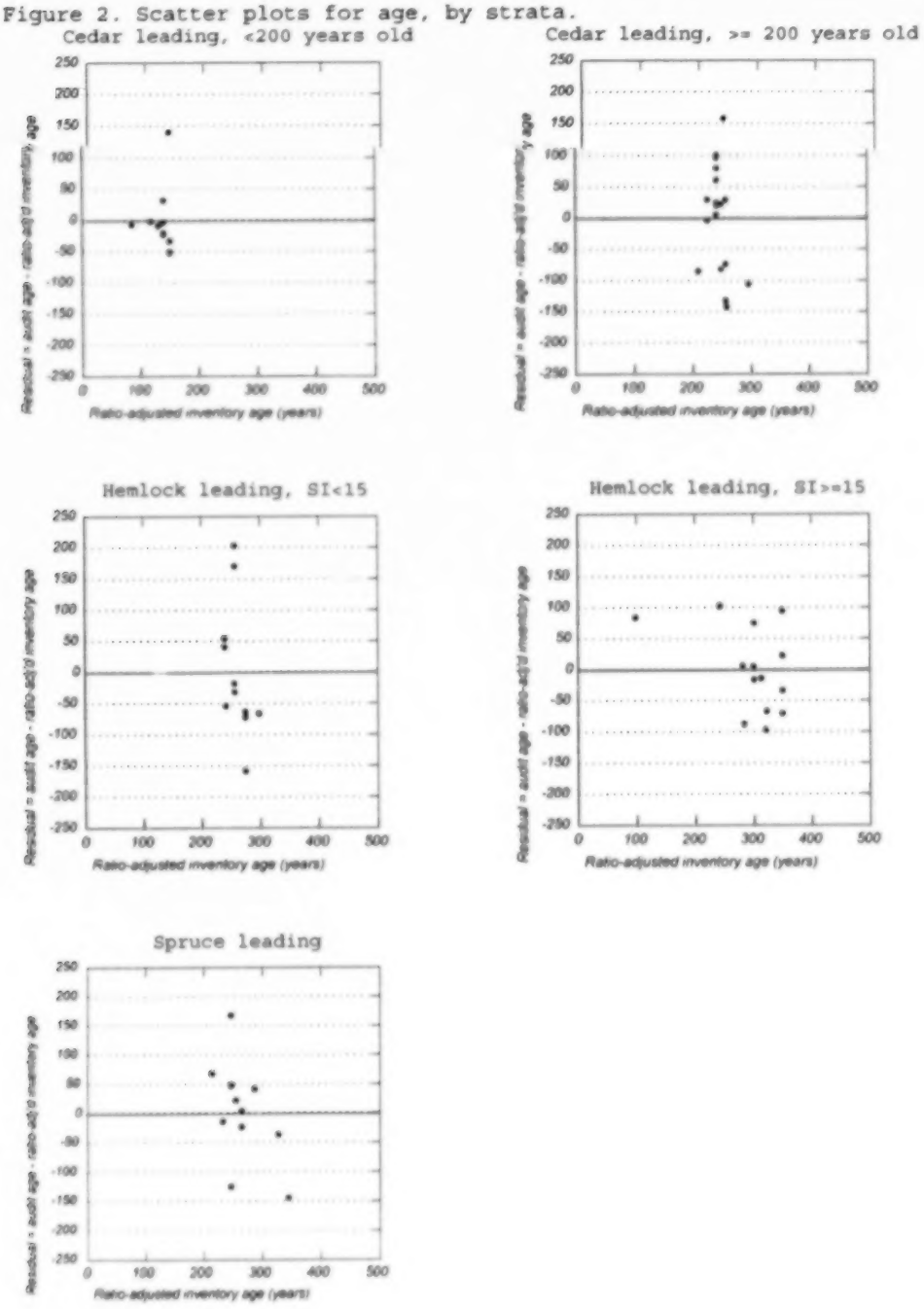


Figure 3. Plot of residuals (audit age - ratio-adjusted inventory age) , by strata.

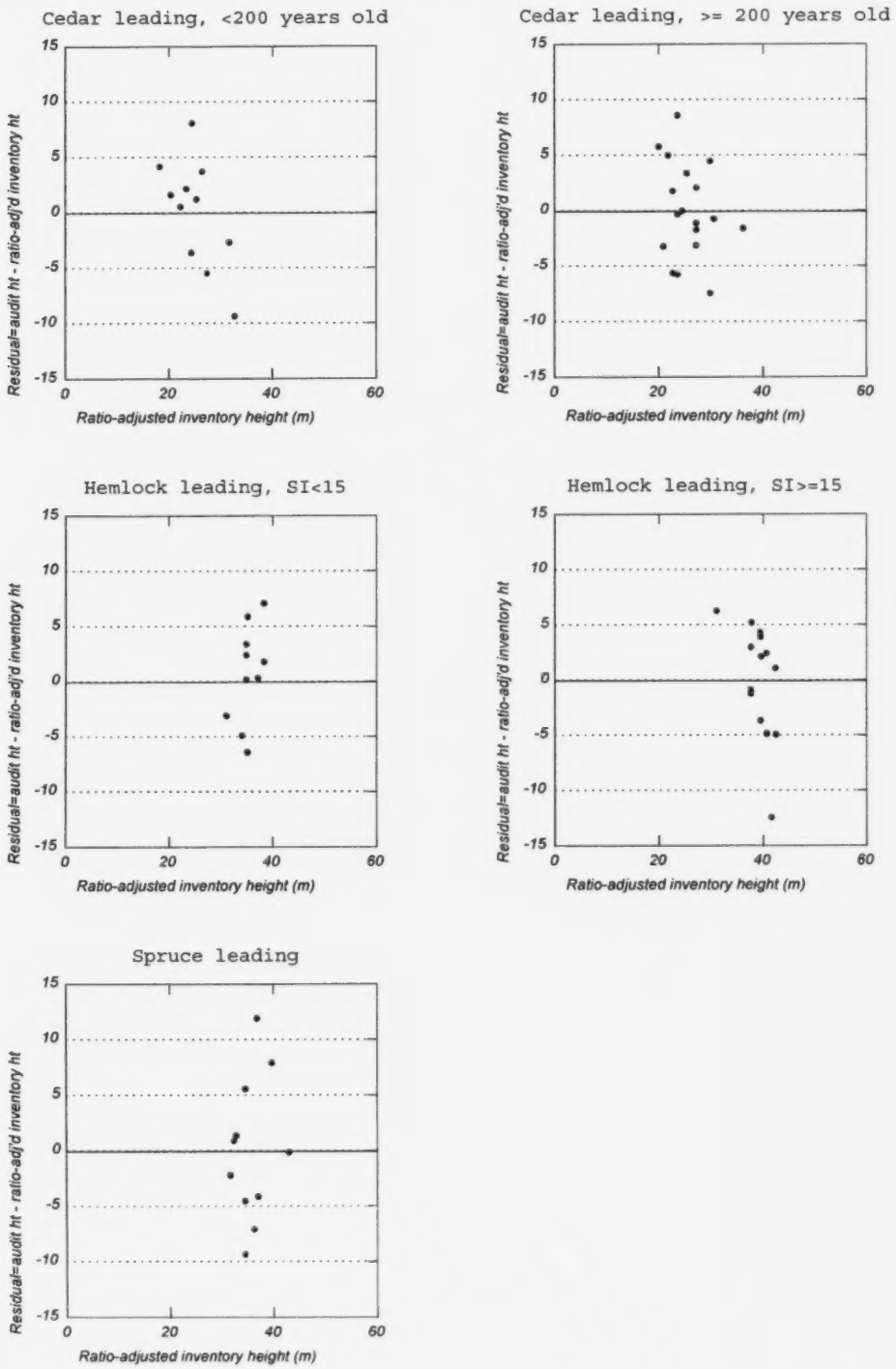


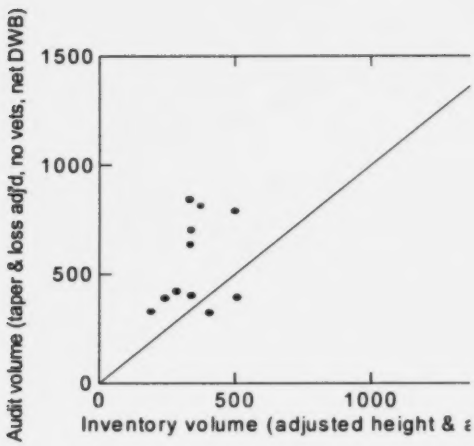
Figure 4. Plot of residuals (audit height - ratio-adjusted inventory height),

by strata.

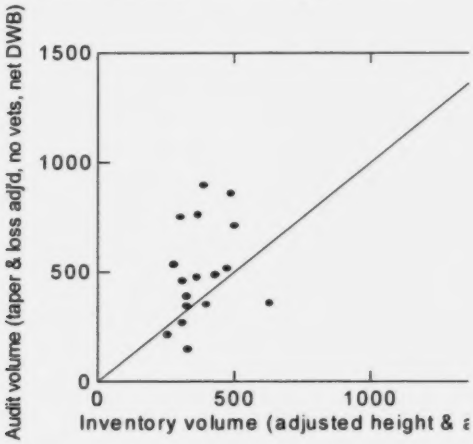
2.6.2 Volume

Scatter plots of the inventory volume (based on adjusted attributes, net decay, waste and breakage) and the audit volume (adjusted for taper and loss factors, without veteran trees, net of decay, waste and breakage) are given in Figures 5 to 8. Inspection of the residual graphs for adjusted volume indicated no apparent trend in bias by adjusted inventory volume (Figure 6), adjusted age (Figure 7), or adjusted height (Figure 8).

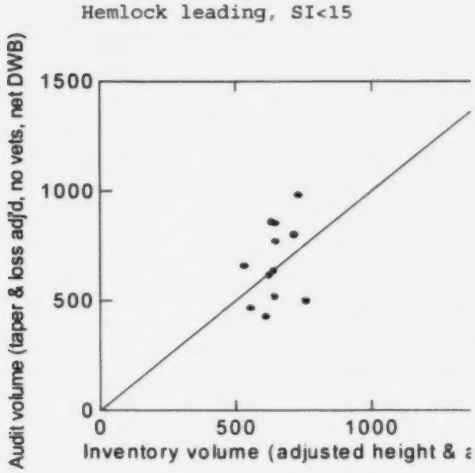
Cedar leading, <200 years old



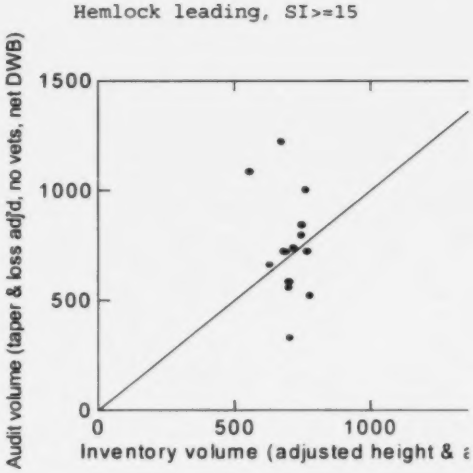
Cedar leading, >= 200 years old



Hemlock leading, SI<15



Hemlock leading, SI>=15



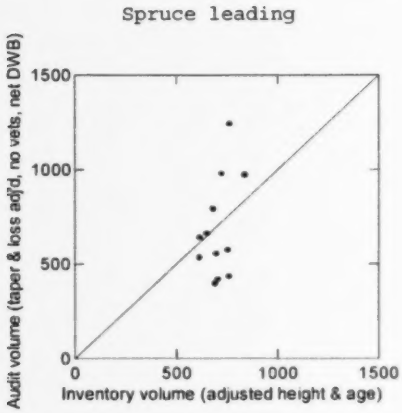


Figure 5. Scatter plots for volume, by strata.

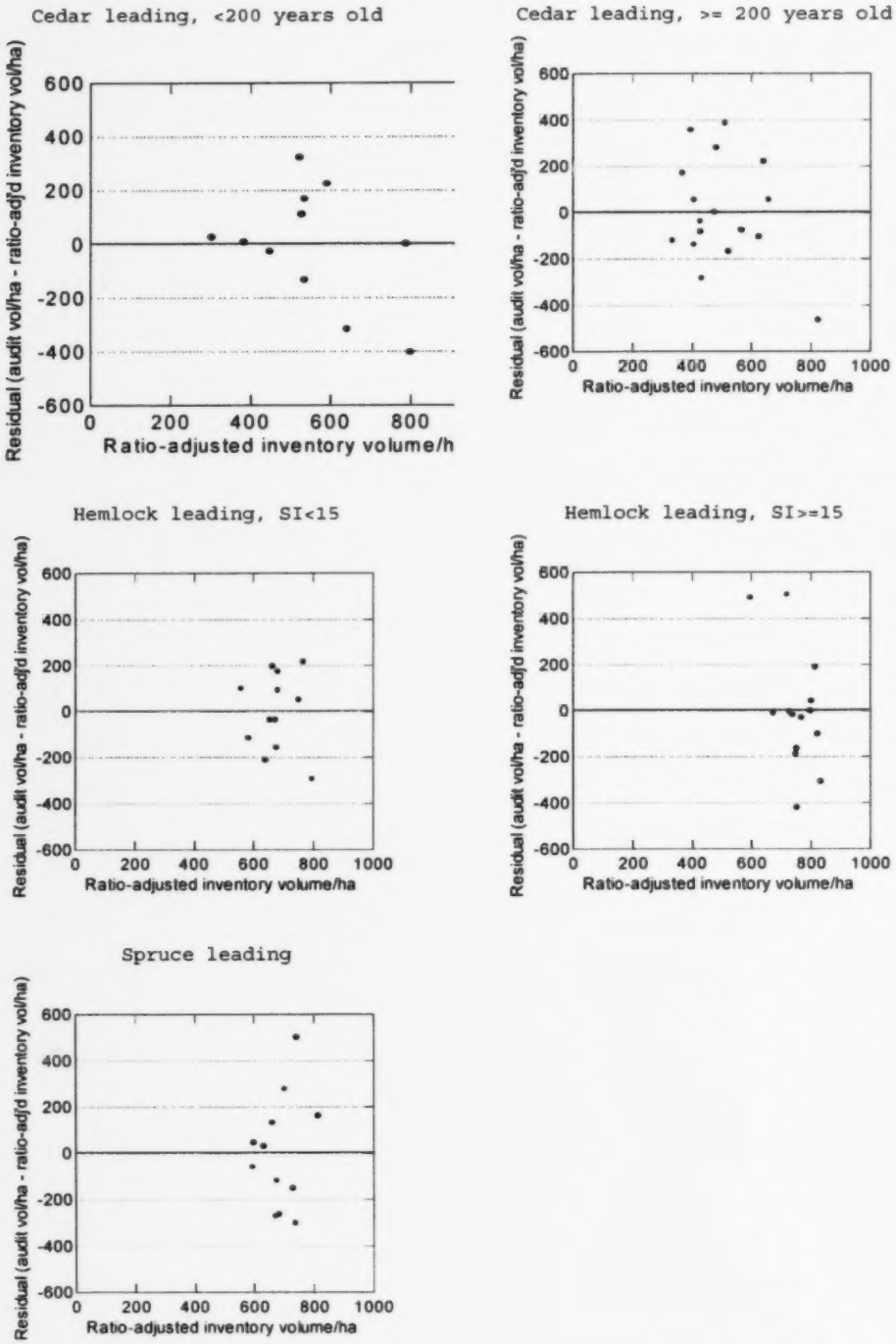
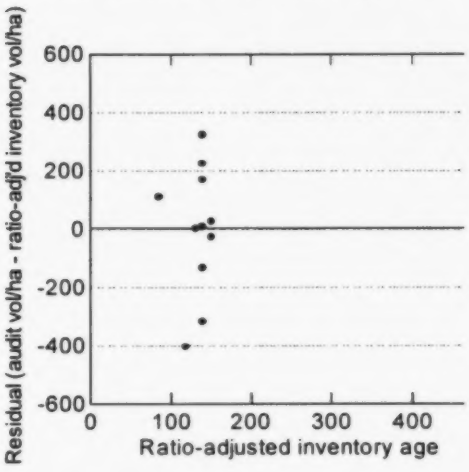
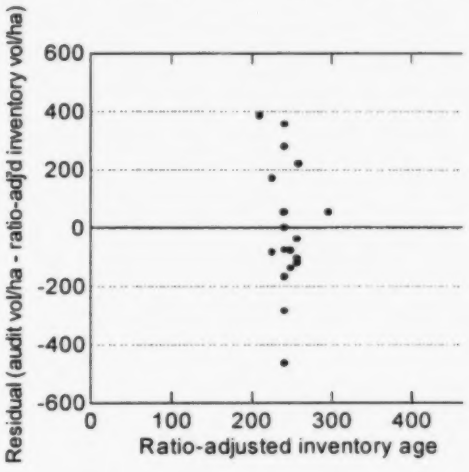


Figure 6. Plots of residuals (audit volume - ratio-adjusted inventory volume) versus ratio-adjusted inventory volume/ha, by strata.

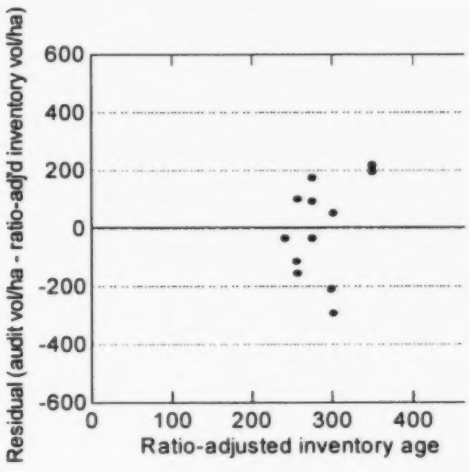
Cedar leading, <200 years old



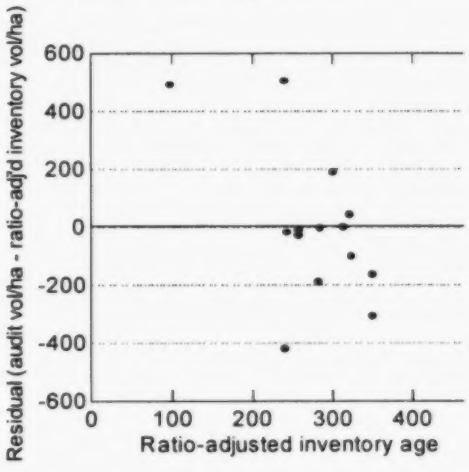
Cedar leading, >= 200 years old



Hemlock leading, SI<15



Hemlock leading, SI>=15



Spruce leading

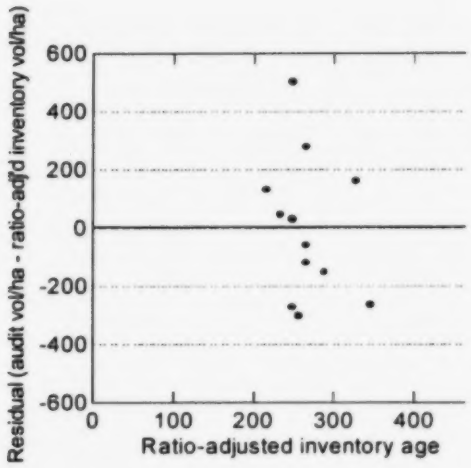
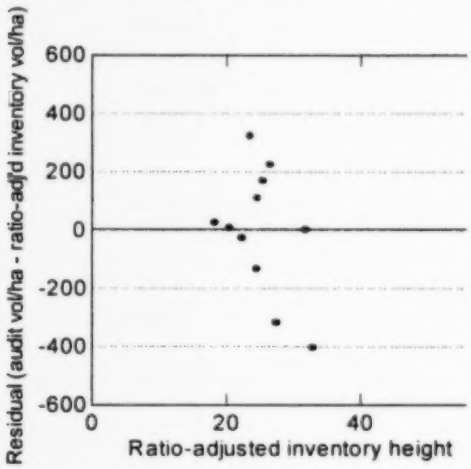
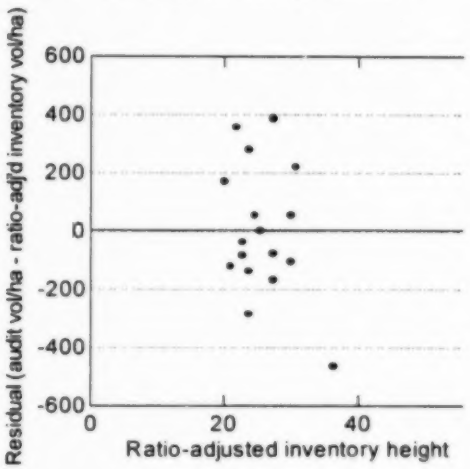


Figure 7. Plots of residuals (audit volume - ratio-adjusted inventory volume) versus ratio-adjusted inventory age, by strata.

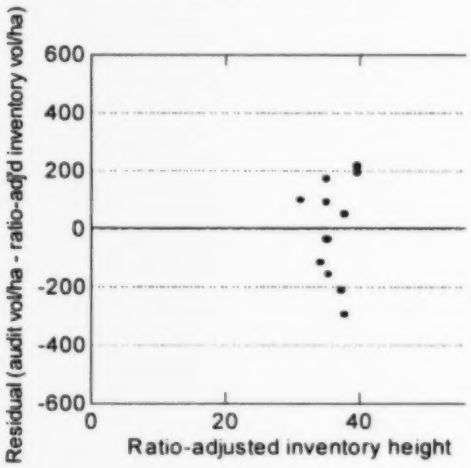
Cedar leading, <200 years old



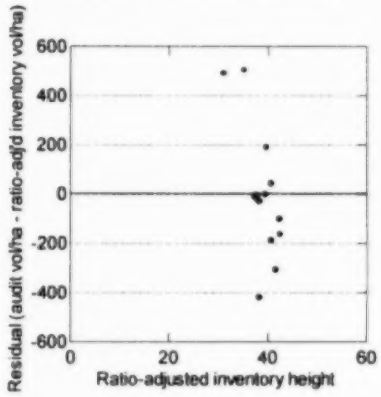
Cedar leading, >= 200 years old



Hemlock leading, SI<15



Hemlock leading, SI>=15



Spruce leading

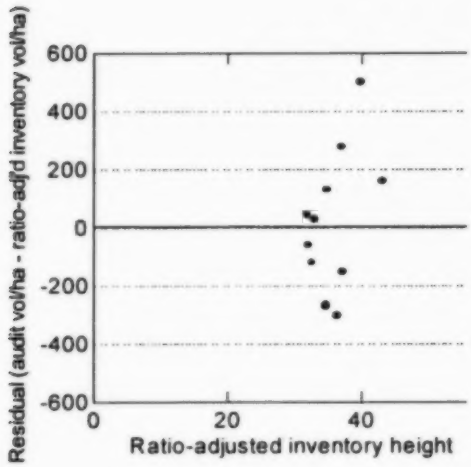


Figure 8. Plots of residuals (audit volume - ratio-adjusted inventory volume) versus ratio-adjusted inventory height, by strata.

2.7 TSA Impact Analysis

To assess the reasonableness of the proposed adjustment approach, we recommend that the adjustment factors be applied to all mature polygons in the timber harvesting land base of the Queen Charlotte Islands TSA file, and the volume impacts evaluated. The difference in total volume between adjusted volume based on the proposed adjustment method and that observed by the inventory audit should be calculated. This difference should be very small. If this is the case, then, essentially, it would confirm that the overall impact of applying the attribute and volume adjustments is similar to that of applying an overall ratio (audit volume ÷ inventory volume) to all polygon volumes.

3. SUMMARY OF RECOMMENDATIONS

The proposed QCI FIP File adjustment process with the following features:

- The purpose is to adjust the existing FIP file to account for the bias detected by the inventory audit and to incorporate the FIZ-based species-specific taper and loss factors adjustments into the inventory.
- The population of interest for adjustment is the mature polygons in the operable land base in the Queen Charlotte Islands TSA.
- Use the inventory audit sample data and the new taper, decay and waste adjustment factors
- Assume that the sample corresponds to the operable landbase.

- The ratio model is used for adjustment of age, top height and volume.
- The volume ratios are based on volume net decay only, and volume net decay, waste and breakage. For timber supply analysis the MOF recommends a utilization level net decay, waste and breakage.
- Several types of volume ratios were provided: volume with veteran trees and volume without veteran trees. For timber supply analysis, the MOF recommends that ratios that include veteran trees be applied.
- The ratios are developed by strata defined as: Cedar leading less than 200 years of age; Cedar leading greater than or equal to 200 years of age; Hemlock leading, SI<15; Hemlock leading, SI>=15; and Spruce leading.
- The adjustment ratios for age, top height and volume are shown in Tables 3-13.
- The overall inventory adjustment without the taper and loss factros adjustments was negligible. The adjustment with the taper and loss factors adjustments was 1.140 (Table 9), and that without was 0.995 (Table 13).

We recommend that the proposed adjustment methodology be implemented, after an impact analysis to determine the overall magnitude of the change to the FIP File when the ratios are applied.

4. APPENDIX I

QCI Audit Sample Compilation Requirements[29]

FIZ-based adjustment factors are based on analysis and formulation by Dr. James Flewelling.[30]

Step 1. Compile all audit samples using standard compiler. Unadjusted Output Volumes Required (m3/ha) by species within sample:

WSV (Whole stem volume) **WSV**
CG10 (Close U volume to a 10 cm top dib) **CG10**
CG10 less Decay **CG10_D**
CG10 less Decay & Waste **CG10_DW**
CG10 less Decay, Waste & Breakage **CG10_DWB**

Step 2. Calculate Breakage Adjustment factors by species(red cedar, hemlock, spruce and yellow cedar) for each polygon. These factors will be applied by species within polygon to the **adjusted** CG10 less Decay and Waste.

Breakage Adjustment Factor[31] F(NB) = CG10_DWB / CG10_DW
Note: NB refers the proportion of volume not broken

Breakage Adjustment Factors will be documented and reported by species within sample(see output below).

Step 3. Compile adjusted audit samples using the appropriate factors in Tables 15 and16.

Note that the waste estimates for all immature red cedar, hemlock and spruce (immature yellow cedar was not sampled) are 0 and the

[29] The notes in this Appendix were provided by Ken Richardson, Ministry of Forests Resources Inventory Branch, Victoria, BC.
[30] Volume and Decay Results Queen Charlotte Islands, December, 1997; and supporting memos including Status16.doc, May 24, 1998 and vdjf025.doc, August 6, 1998.

decay estimate for spruce is 0. It is not possible to calculate F(D) and F(W) for these species/age combinations as the estimate is the denominator of the ratio being calculated. It is recommended to use the decay and waste estimates directly from the V&D study for all immature red cedar, hemlock and spruce. The direct decay and waste adjustments are in Table 17. The calculations of the adjusted volumes for these species/maturity combinations are shown below in Step 4.

Table 14. Volume Adjustment Factors.

Species	Sample Age Range	Whole Stem Volume (taper) Adjustment Factor [F(WSV)]	Non-utilizable Top and Stump Volume (taper) Adjustment Factor [F(NON_U)]
Cw	1-120	1.0578	1.1861
Cw	121+	1.1538	1.2230
H	1-120	0.9699	1.3710
H	121+	1.0191	1.5515
Ss	1-120	1.0736	1.0215
Ss	121+	1.0877	1.0944
Y	1-120	1.0	1.0
Y	121+	1.1114	1.5456

Table 15. Mature Decay and Waste Volume Adjustment Factors.

Species	Sample Plot Age Range	Decay Volume Adjustment Factor F(D)	Waste Volume Adjustment Factor F(W)
Cw	121+	0.2729	0.1709
H	121+	0.4176	0.1286
Ss	121+	1.3829	1.5293
Y	121+	0.3907	0.2962

[31] James Flewelling, personal communication, Aug. 4, 1998

Table 16. Immature Direct Decay (DECAYest) and Waste (WASTEest) volume estimates (m3/ha) for calculation of adjusted immature sample volumes.

Species	Sample Plot Age Range	DECAYest m3/ha	WASTEest m3/ha
Cw	1-120	0.6457	0.0026
H	1-120	0.2708	0.0309
Sw	1-120	0.6793	0.3605
Y	1-120	0	0

Step 4. Summarize output by species within sample (17 variables):

WSV Unadjusted Whole Stem Volume
CG10 Unadjusted Close "u" Volume
CG10_D Unadjusted Close "u" Volume less decay
CG10_DW Unadjusted Close "u" Volume less decay, waste
CG10_DWB Unadjusted Close "u" Volume less decay, waste, breakage
F(WSV) Whole Stem Volume Adjustment Factor
F(NON_U) Non-utilizable Stump/Top Volume Adjustment Factor
F(D) Decay Adjustment Factor - Mature Samples
F(W) Waste Adjustment Factor - Mature Samples
DECAYest Direct Decay Adjustment Estimate - Immature Samples
WASTEest Direct Waste Adjustment Estimate - Immature Samples
F(NB) Breakage Adjustment Factor

ADJUSTED VOLUMES FOR MATURE POLYGON SAMPLES

A_WSV = [WSV*F(WSV)] Adjusted WSV for taper
A_CG10 = A_WSV - [{WSV-CG10}*F(NON_U)] Adjusted CG10 for taper
A_CG10_D = A_CG10 - [{CG10-CG10_D}*F(D)] Adjusted CG10 less D
A_CG10_DW = A_CG10_D - [{CG10_D-CG10_DW}*F(W)] Adjusted CG10 less D+W
A_CG10_DWB = A_CG10_DW*F(NB) Adjusted CG10 less D+W+B

ADJUSTED VOLUMES FOR IMMATURE POLYGON SAMPLES

```
A_WSV = [WSV*F(WSV)]                    Adjusted WSV
A_CG10 = A_WSV - [{WSV-CG10}*F(NON_U)]      Adjusted CG10
A_CG10_D = A_CG10 - DECAYest          Adjusted CG10 less D
A_CG10_DW = A_CG10 - DECAYest  - WASTEest    Adjusted CG10
                                              less D+W
A_CG10_DWB = A_CG10_DW*F(NB)          Adjusted CG10 less
                                                D+W+B
```

EXAMPLE 1: ADJUSTED VOLUMES FOR MATURE POLYGON SAMPLES

Data:

WSV = 155.7
CG10 = 143.91
CG10_D= 120.26
CG10_DW = 112.09
CG10_DWB = 102.02

Calculations:

```
A_WSV   = [WSV*F(WSV)]
          =155.7 * 1.1538
          = 179.64

A_CG10  = A_WSV - [{WSV-CG10}*F(NON_U)]
          =179.64 - [(155.7-143.91) * 1.223]
          = 165.22

A_CG10_D  = A_CG10 - [{CG10-CG10_D}*F(D)]
          =165.22 - [(143.91 - 120.26) * 0.2729]
          = 158.77

A_CG10_DW = A_CG10_D - [{CG10_D-CG10_DW}*F(W)]
          = 158.77-[(120.26 - 112.09)] * 0.1709
          = 157.37

A_CG10_DWB   = A_CG10_DW*F(NB)
               = 157.37 * 0.9102
               = 143.24
```

EXAMPLE 2: ADJUSTED VOLUMES FOR IMMATURE POLYGON SAMPLES

Data:

WSV = 236.47
CG10 = 226.48
CG10_D = 202.29
CG10_DW = 202.29
CG10_DWB = 190.96

Calculations:

A_WSV = [WSV*F(WSV)]
= 236.47 * 0.9699
= 229.35

A_CG10 = A_WSV - [{WSV-CG10}*F(NON_U)]
= 229.35 - [(236.47 - 226.48) * 1.371
= 215.65

A_CG10_D = A_CG10 - DECAYest
= 215.65 - 0.2708
= 215.37

A_CG10_DW = A_CG10 - DECAYest - WASTEest
= 215.65 - 0.2708 - 0.0309
= 215.34

A_CG10_DWB = A_CG10_DW*F(NB)
= 215.34 * .944
= 203.28